COMMENTS ON A COOPERATIVE R. F. TECHNIQUE FOR COLLISION-HAZARD WARNING

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(Text used during panel presentation)

Langley Research Center is investigating the feasibility of a relatively simple, cooperative, radio frequency warning system. This system utilizes a transponder designed to reply to interrogating aircraft with a c.w. signal containing a true doppler term. This doppler term is used in conjunction with the basic range limitation imposed by transmitter power to help discriminate between hazardous and nonhazardous intruding aircraft. Efforts to date have consisted of a preliminary study of the systems problems in addition to some experimental work on the antenna and transponder design problems.

The first figure lists some of the general characteristics which we feel can be obtained. Minimum complexity in the transponder is desirable for two reasons. First, this results in a relatively low cost for the minimum installation, i.e., transponder only; and, second, this minimizes the overall system dependence on transponder performance. The transponder can reply to multiple interrogations simultaneously. All aircraft operate at the same frequency assignments eliminating the need for individual channel allocations for each aircraft. The range of protection can be controlled by the protected aircraft by controlling the transmitter power and receiver sensitivity. To a degree, the type of measurements and their accuracies may be controlled by the protected aircraft.

Figure 2 shows a functional diagram of this system. Two aircraft are shown. The protected aircraft contains a pair of transmitters, a receiver and display unit, and should also contain a transponder; and the intruding aircraft contains a transponder, and may also contain transmitters and receiver. In operation, the protected aircraft transmits a pair of c.w. signals which are received and multiplied in the transponder to generate the difference frequency which is then retransmitted. Random transmitter coding is employed to suppress the spurious signals generated with multiple interrogations. Utilizing an analog multiplier and linear output amplifier in the transponder results in the retransmitted power being proportional to $1/R^4$. The received signal level at the protected aircraft varies proportional to $1/R^6$. The resultant signal strength, therefore, decreases rapidly as range

increases. The frequency of the received signal is compared with the difference of the transmitted pair to determine the doppler shift or closing velocity. This is incorporated in the receiver to make its threshold vary as a function of closing velocity as well as range.

Figure 3 indicates one type of threshold characteristic which can be obtained relatively simply. It can be seen that this characteristic approaches a constant tau ($R/\dot{R}$) warning at long ranges and a constant range warning at short ranges.

Figure 4 indicates the type of coverage which can be obtained considering realistic antenna patterns. This is based on a transponder antenna which is omnidirectional in the plane of the aircraft with a 24° beamwidth in the vertical plane. The transmitter and receiver patterns are fan shaped covering $\pm 100°$ from the nose with the indicated vertical beamwidths. These curves are normalized since the actual coverage is variable as a function of the effective radiated power from the transmitter and the sensitivity of the receiver. A five mi. system, for example, will provide vertical coverage of approximately ± 1500 feet to ± 3000 feet, depending on the beamwidths employed.

Figure 5 indicates a relatively simple method of utilizing the system. In this approach, the presence of intruding aircraft in given sectors is indicated. A more sophisticated detection system is illustrated on the next slide (figure 6). Here, individual intruding aircraft are detected based on a separation of doppler frequency (closing velocity), and the individual direction angles are displayed.

At present, we feel that a system can be developed where the basic installation consists of a relatively simple transponder capable of replying to a number of aircraft simultaneously, and where the degree of protection provided to an individual aircraft is primarily a function of the equipment contained in the protected aircraft. We are continuing this investigation with emphasis, at present, on what appear to be the most difficult problems; the antenna design and the decoupling between the transponder and interrogating radar.

COOPERATIVE R.F. WARNING SYSTEM

- MINIMUM REQUIRED COMPLEXITY IN TRANSPONDER
- MULTI-AIRCRAFT CAPABILITY
- INDIVIDUAL CHANNEL ASSIGNMENTS NOT REQUIRED.
- DETECTION RANGE DETERMINED BY PROTECTED AIRCRAFT
- MEASUREMENTS DETERMINED BY PROTECTED AIRCRAFT

FIGURE 1.

FUNCTIONAL SYSTEM DIAGRAM

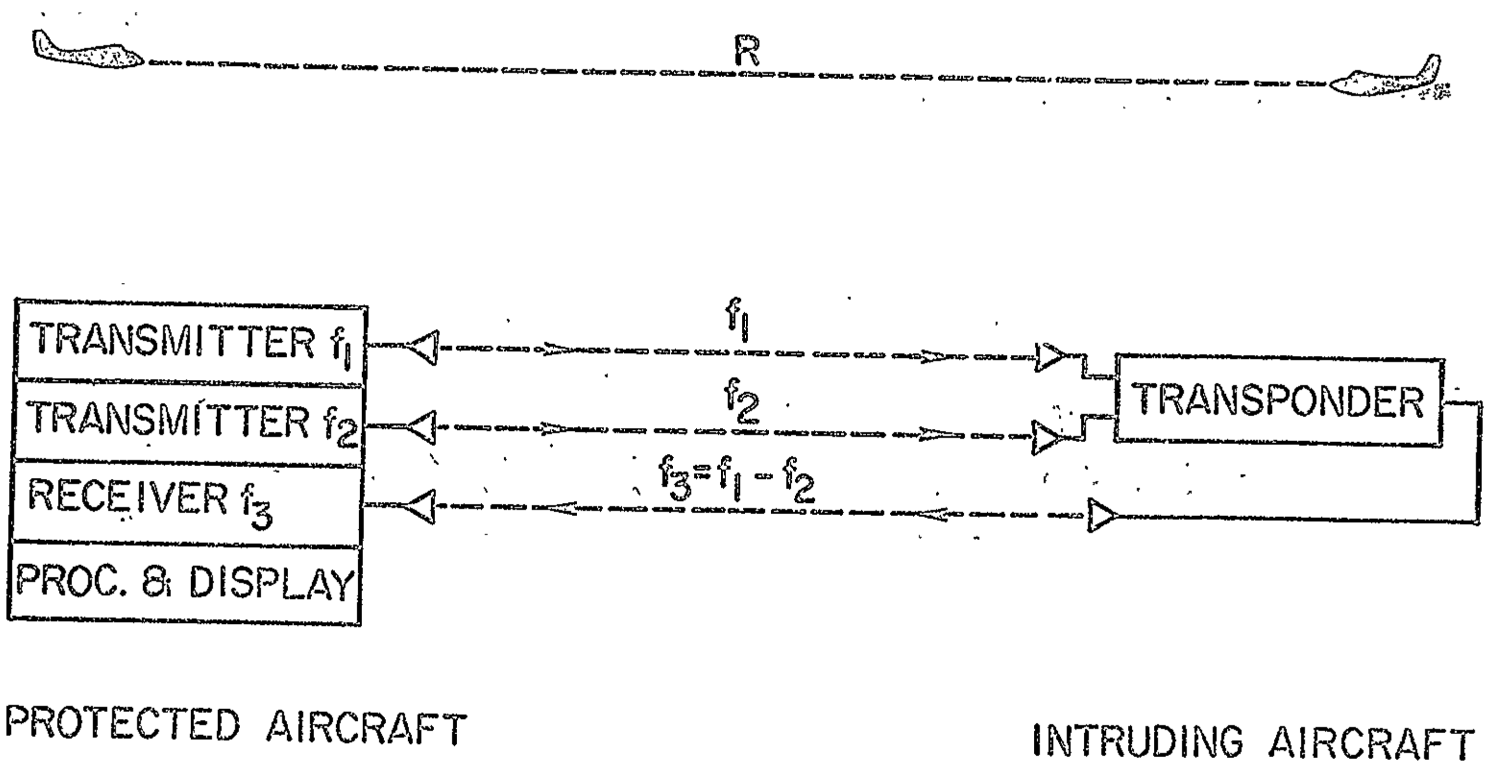

FIGURE 2.

R^3/V_c THRESHOLD CHARACTERISTIC

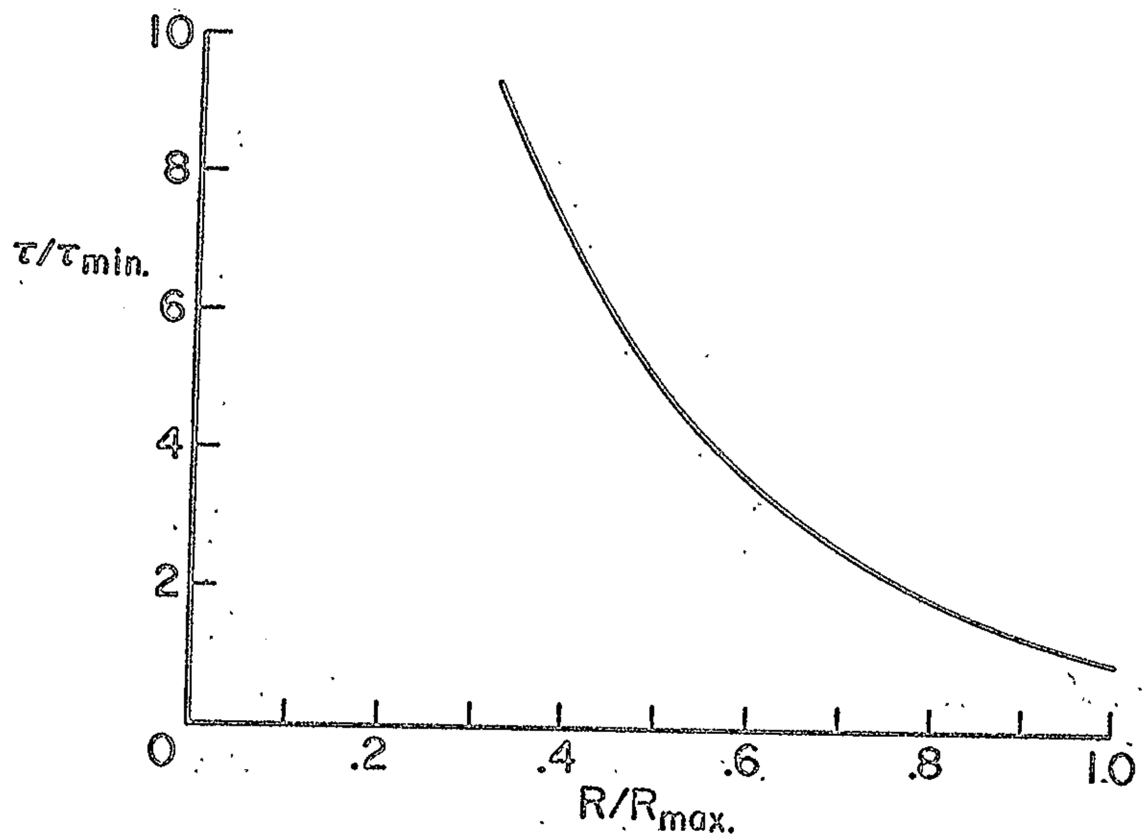

FIGURE 3.

VERTICAL COVERAGE

CURVE	30 dB BEAMWIDTHS OF ANTENNAS TRANSMITTER	RECEIVER	TRANSPONDER
A	24°	24°	24°
B	12°	24°	24°
C	6°	12°	24°

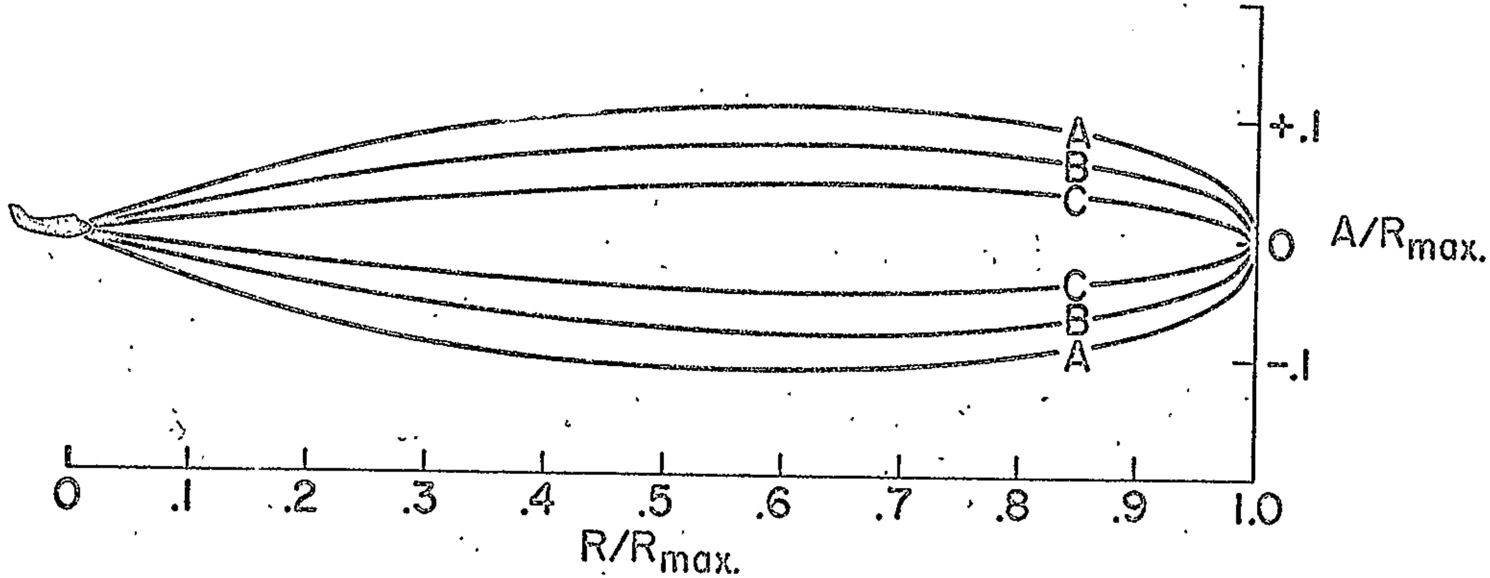

FIGURE 4.

SECTOR DETECTION

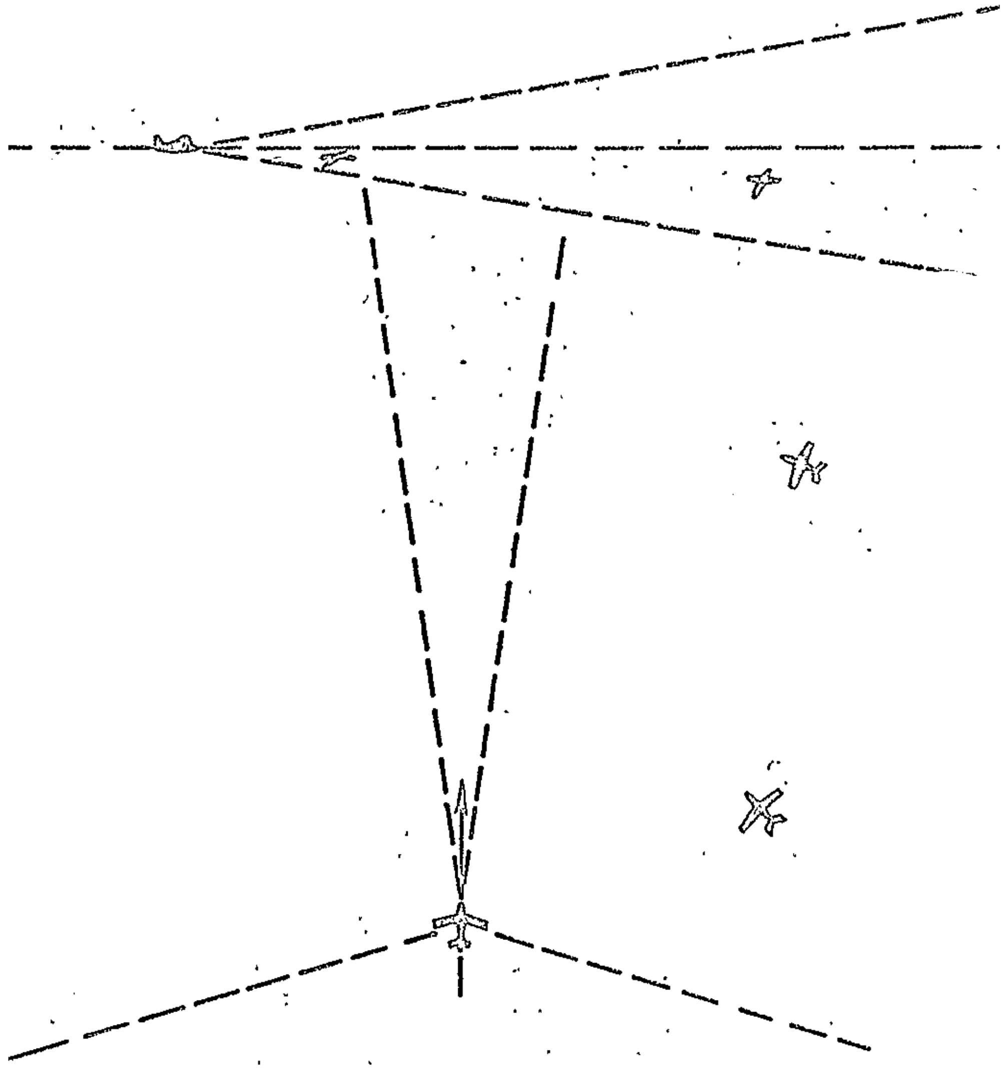

FIGURE 5.

INDIVIDUAL INTRUDING AIRCRAFT DETECTION

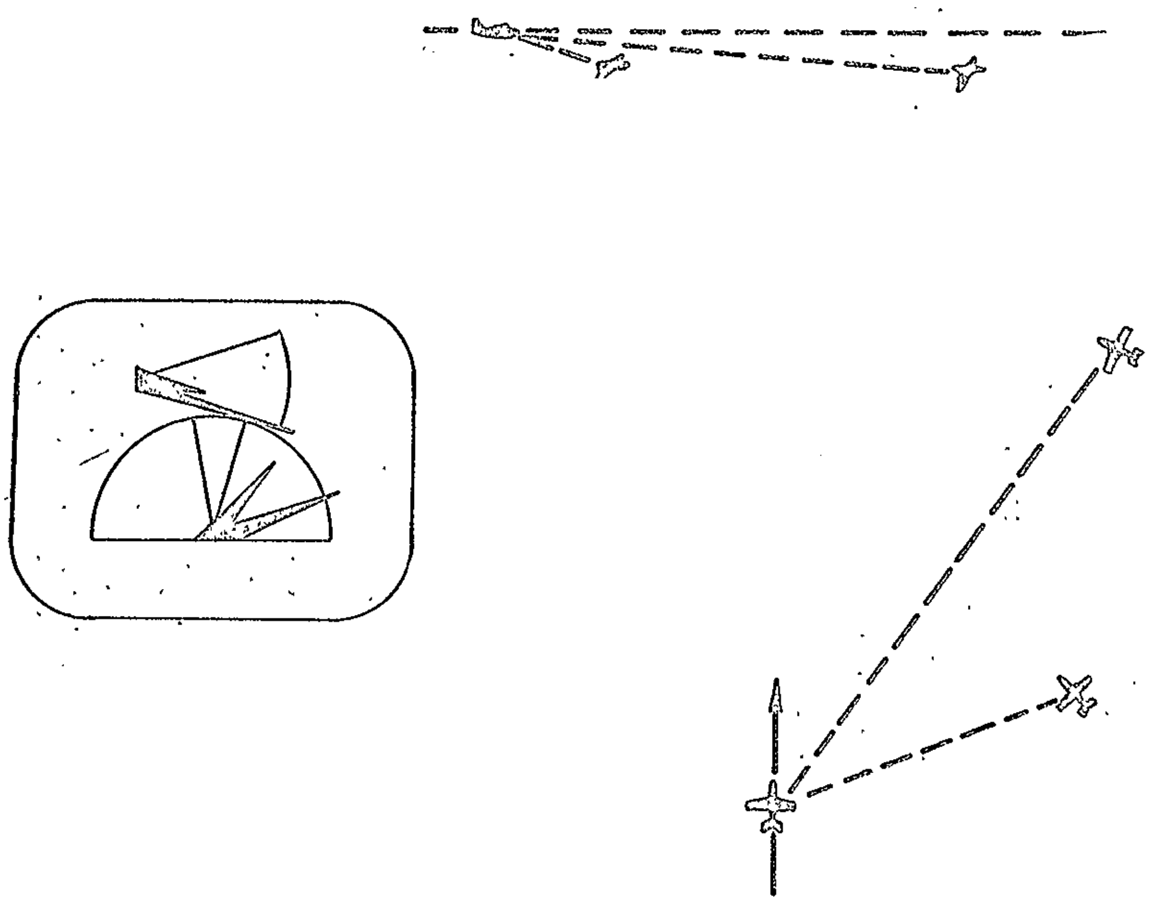

FIGURE 6.